AD-A168 970 AN APPLICATION OF A LISP BASED EXPERT SYSTEM FOR FAILURE DIAGNOSIS OF THE..(U) PRINCETON UNIV NJ DEPT OF MECHANICAL AND AEROSPACE ENGINEERIN.. C J LOH 1/1

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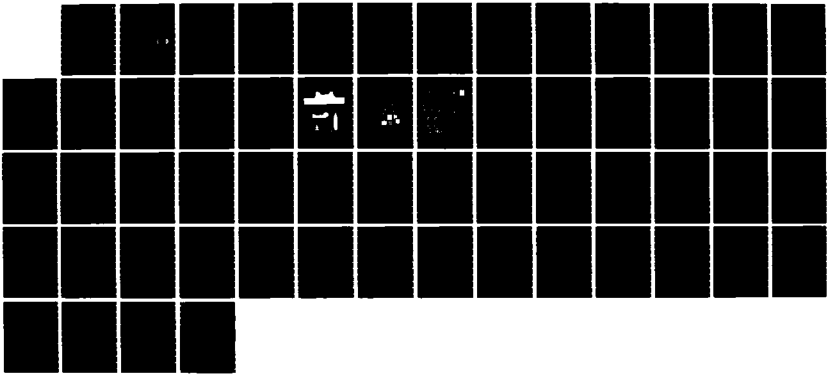

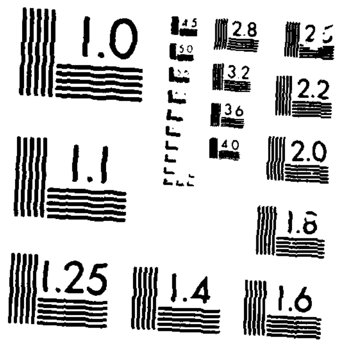

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An investigation of the hydraulic flight control system of a Boeing CH-47 Chinook helicopter utilizing artificial intelligence techniques will be undertaken. Specifically, a *knowledge based expert system* will employ situation-action rules (production rules) to diagnose a failure and subsequently iden-

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20. ABSTRACT CONTINUED

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AN APPLICATION OF A LISP BASED EXPERT SYSTEM FOR FAILURE DIAGNOSIS OF THE CH-47 FLIGHT CONTROL HYDRAULIC SYSTEM

Interim Technical Report
1741-MAE

Christopher J. Loh

March 2, 1986

U. S. ARMY RESEARCH OFFICE
Research Triangle Park, NC

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ABSTRACT

An investigation of the hydraulic flight control system of a Boeing CH-47 Chinook helicopter utilizing artificial intelligence techniques will be undertaken. Specifically, a *knowledge based expert system* will employ situation-action rules (production rules) to diagnose a failure and subsequently identify specific device(s) which caused that failure. Moreover, because the behavior of the system is directly responsive to the goals the system is attempting to achieve, the expert system's inference engine performs a backward-chaining process via a goal-driven control strategy. The *List Processing Language* (*LISP*) is used to facilitate data processing and symbolic logic expression.

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GENERAL BACKGROUND

The CH-47 Chinook twin-rotor helicopter is an exceedingly complex flying machine (*FIGURE 4*). As in all complicated apparatuses, failures must be detected immediately and implementation of corrective procedures must be performed quickly especially when human life is at stake. The project's present goal is to provide an interactive system which can diagnose failures and propose possible corrective procedures for the damaged flight control hydraulic system. Aspects of Artificial Intelligence (AI) relating to expert systems are implemented. The AI field is relatively new with regard to implementation of expert systems for failure diagnosis of complicated systems. Hence, this research should prove not only interesting because of its "cutting edge" nature in the AI field, but also useful in its practical applications for efficient and effective failure diagnosis.

EVOLUTION OF ARTIFICIAL INTELLIGENCE

AI originated in the 1950's through the efforts of several computer scientists investigating new methodologies to solve old problems through symbolic programs. Results in automated deduction and problem-solving produced great enthusiasm. During the last two decades, AI researchers recognized the value of domain specific knowledge as a basis for solving significant problems [1]. However, at the same time, researchers also realized that generic problem-solving strategies cannot solve the world's most challenging problems. To solve a problem in the field of engineering, finance, or medicine, for example, machine problem-solvers found it necessary to understand human problem- solvers way of thinking about a particular subject. The computer offers many advantages over the human mind - such as speed and consistency - but lacks the ability to compensate for ignorance [1]. In short, AI researchers concluded that high IQ does not necessarily make a person an expert, but specialized knowledge will. For a fast and consistent symbol processor to perform as effectively as a human expert, the machine must possess the specialized knowledge and reasoning capabilities that a human expert inherently possesses. This need evolved into the field of knowledge engineering and resulted in the growth of *expert systems*.

ROLE OF EXPERT SYSTEMS

Expert systems are intelligent computer applications that use data, a knowledge base, and a control mechanism to solve problems of sufficient difficulty in which significant human expertise is necessary for their solution. Expert systems use AI problem-solving and knowledge representation techniques to combine human expert knowledge concerning a problem area with human expert methods of conceptualizing and reasoning about that problem area [2]. Therefore, such a system can feasibly achieve the level of performance of a human expert in a specialized problem area. The high level knowledge base and its associated control mechanism are essentially the expert's knowledge and reasoning capabilities coded via a high level programming language.

KNOWLEDGE BASE LEVEL

The most prevalent technique utilized in organizing knowledge bases is that of forming production rules which become connected to one another by *if-then* statements which build rule networks. Rules in the knowledge base represent both facts and heuristics - facts being discrete pieces of information that is generally accepted; heuristics being little discussed rules of thumb that characterize expert-level decision making in the problem area. Both facts and heuristics are generated throughout the session directly resulting from system inferences and user intervention.

INFERENCE ENGINE

The control structure or inference engine of an expert system makes decisions about how to use the system's knowledge by organizing and controlling the steps needed to solve current problems. The control mechanism is actually a collection of procedures or strategies on how to solve problems. A common but powerful problem-solving mode of rule based systems involves the chaining together of if-then rules to form a line of reasoning. This project implements a technique of backward-chaining which has had proven success in systems for diagnosis and planning. In backward-chaining, the conclusion is assumed but the path to it is not, as in the case of goals and hypotheses. These rules work from goals to subgoals by using the action side of rules to deduce the condition of rules. Specifically, the control mechanism scans the rule base to find those rules whose consequent actions can achieve the desired goal. Each of these rules is tried in succession. If the antecedent side of the rule correlates to the existing conditions in the working memory (coined by J. McDermott in "*R1: An Expert in Computer Systems Domain*") [3], then the rule is fired and the subgoal is achieved. However, if an unmatched antecedent is encountered, that antecedent becomes a new subgoal, and the same procedure is applied recursively. If there are no rules to establish that subgoal, the system prompts the user for additional information.

Without the appropriate heuristics for guidance, backward-chaining will encounter problems in handling conjunctive subgoals [2]. In general, this requires finding a case where all interacting subgoals are satisfied, a search that in the worst case could result in an overload of information. Thus, in addition to appropriate heuristics, suitable inferences and architectures must be found for each type of problem area in order to achieve an efficient and effective expert system.

As an example, the following illustration concisely depicts the basic structure of a knowledge based system [3].

H = hypothesis

P = proof

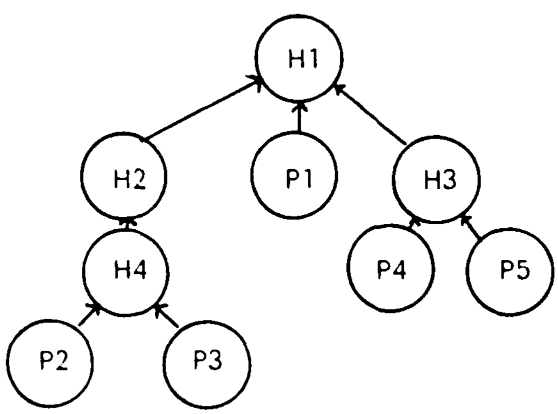

FIGURE 1

Backward-chaining initially analyzes the truthfulness of H1 by determining the values of H2, H3, where P1's value is known. To determine the value of H2, the system must look at the value of H4. To conclude H4, the system must look at P2 and P3's values. Finally, to determine the value of H3, the system must inspect P4 and P5. In other words, the system determines the value of the premise by first concluding the value of the associated action. The associated action then becomes the premise of another node further down the tree, and the process repeats until all hypotheses are determined by the values of their evidences. The present system incorporates many judgmental and empirical rules according to which the evidence supports a conclusion or hypothesis. As a final note, rules are neither implemented as subroutines nor embodied in any other part of the program code. The program uses rules as input to produce an internal representation which provides the expert system with expert knowledge specific to the task domain. The program itself is an interpreter and general reasoning mechanism. This important fact distinguishes the knowledge base from the inference engine.

INITIAL ASSUMPTIONS

The present knowledge base assumes a closed world rule space. In other words, the knowledge base by default assumes that the only causal effects which result in device failures are those that are coded in the parameters and rules. Of course, the rules are only as comprehensive as the source from which they were derived. Operation and maintenance manuals were used as primary sources of information. There are certain cases in the knowledge base in which no rules can be used to determine the value of a particular parameter. Instead, the user is asked to provide the value of the unknown parameter. As more knowledge is accumulated about the system, the knowledge engineer can refine and perfect the knowledge base and eventually obviate any unnecessary user intervention. The present system derives its credibility from the accuracy and "expertness" of the aforementioned manuals. Further contact with Army personnel or the helicopter manufacturer either via interviews or correspondences would be ideal and desirable.

DESCRIPTION OF OPERATION

The flight control hydraulic system consists of two separate and independent systems [4]. Specifically, the two systems are parallel in operation, hydraulically separated, and electronically integrated [5]. The system provides boost to the pilot for flight control movements. The normal operating pressure is between 2500 and 3200 psi pressure. Any pressure below 2500 psi is characterized by the system as abnormally low and pressure above 3200 psi is considered abnormally high. Each system has its own hydraulic tank, pump, plumbing installations, and the concomitant valves, filters, and fittings. The flight control systems are labeled No.1 and No.2 and the HYDRAULIC BOOST switch on the control panel in the cockpit allows the pilot to alternate between systems when one system fails. Furthermore, each system provides hydraulic pressure to operate the forward and aft pivoting and swiveling dual-actuating cylinders, the Stability Augmentation System (SAS), dual extensible link actuating cylinders, and dual stick boost actuating cylinders. The expert system's qualitative reasoning can be applied separately and independently to either flight control system. The expert system arbitrarily treats all data as referring to flight control system one. Any references to the other system are by default flight control system two.

The actual programs and initial knowledge base are listed in the appendices. Specifically, Appendix A presents a list of parameters called upon and implemented in the knowledge base. Appendix B presents the schematic representation of the knowledge base in which a logical upward causal flow is evident. Finally, Appendix C presents the actual code written in LISP. The English translation of the rules is also included.

The following diagram (*FIGURE 2*) is a schematic flow of the working fluid through the system. Its purpose is to provide for the user a *general* idea of the flight control system's operation methodology. *FIGURE 5* and *FIGURE 6* provide the flight control hydraulic system layout as diagrammed in reference 5.

As a note to the following page, if a pump malfunction causes the system to overpressurize, the pressure relief valve is set to crack open at 3160 to 3850 psi. The accumulator acts as a damper to absorb low frequency pressure surges in the pressure line.

THEORY OF OPERATION

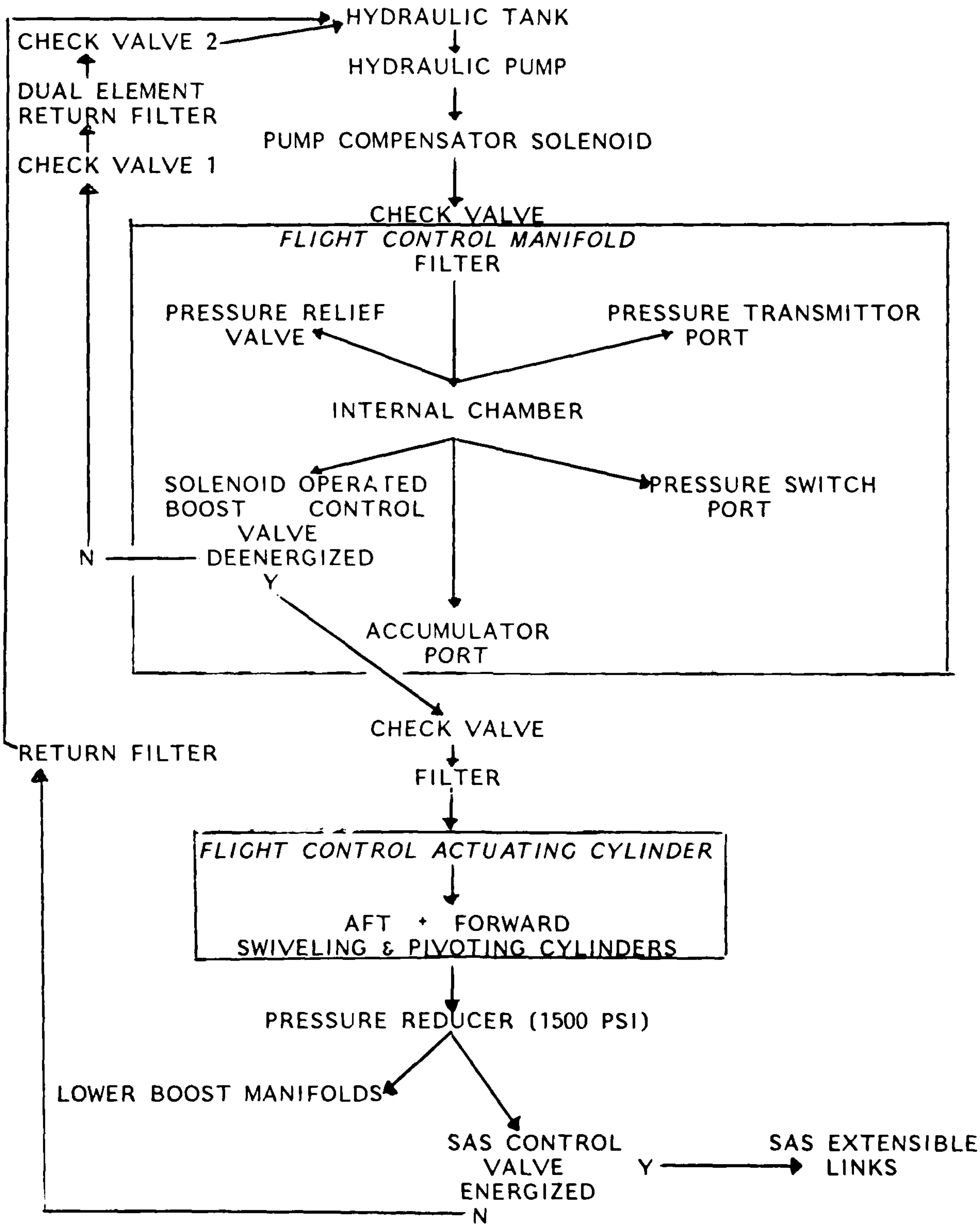

FIGURE 2

DISCUSSION OF PARAMETERS AND RULES

The knowledge base rule tree has essentially four major levels as illustrated in the following figure.

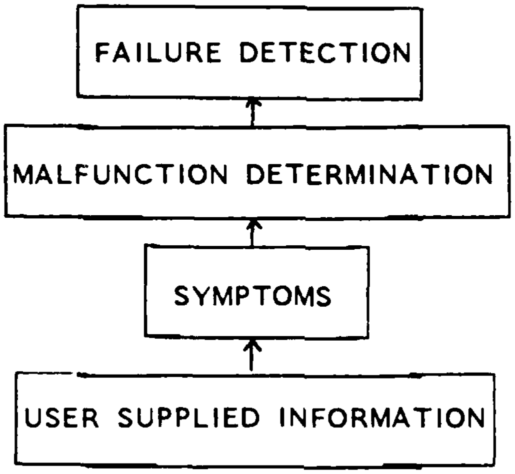

FIGURE 3

The controller uses the backward-chaining technique beginning from the top level and working itself down the tree to determine various parameters. More important than determining whether a failure is detected is deducing the specific devices which failed during the session. The inference engine hypothesizes the failure of a particular device - such as the pressure transmitter, for example. The inference engine, after internalizing the knowledge base by separating the antecedent and action side of all rules and developing a master list of parameter rule relationships, scans down this list which has the device failure in question in its action clause. In order to prove the action, the engine must prove the antecedent. This becomes the new subgoal and hence the motivation behind the use of a backward-chaining search. The search scans all rules using a left-to-right ordering preference. For instance, in the top level tree in Appendix C, Rule 001 is fired before Rule 002. Hence, the absolute position of a rule in the master rule list is irrelevant; its relative position to related rules however is crucial to the expert system's efficiency and ultimately its search speed. Primary rules are fired before secondary rules so that conclusions can be deduced more quickly. Instances where rules are not found to be applicable to a particular parameter determination may occur, and the system prompts the user for the necessary information. This should not be interpreted as holes in the knowledge base per se. In most cases, the nature of the data requested by the system has to be asked (i.e. the pressure value). In real life situations, a pressure value would be read from the pressure gage. However, there are cases where the knowledge base may appear to lack needed information. This aspect will be ameliorated as a more complete understanding of the flight control system is achieved. A possible implementation - use of pressure sensors or check valves at strategic points along the system - could be used to automatically detect failures.

PROGRESS AND IMMEDIATE GOALS

A portion of the first semester has been devoted to researching the field of artificial intelligence, especially the manner in which it applies to expert systems. Subsequent time has been dedicated to mastering the fundamental programming concepts of LISP and in particular the use of list manipulation and backward-chaining techniques. An introduction to the *Personal Consultant* (*TM*) software package written by Texas Instruments has also been performed [6]. Furthermore, the latter half of the semester has been devoted to the understanding of the CH-47 flight control hydraulic system. A first cut at a knowledge base representation for determination of device failures is presented later in this progress report. Much more work needs to be done in this respect; in particular, to derive further heuristics in order to improve the quality and *efficiency of the* knowledge base. Hopefully, consultation with experts will be of use.

FUTURE PLANS

The immediate goal for the second semester is to load the present knowledge base onto the *Personal Consultant* (*TM*). Then a process of refinement and enlargement of the existing system will be undertaken. By the installment of further heuristic rules through embellishment of the present system, the knowledge base should be even more effective and efficient. Since the pneumatic system is so inherently linked to the hydraulic system, the former system will also be added.

CH-47 HELICOPTER

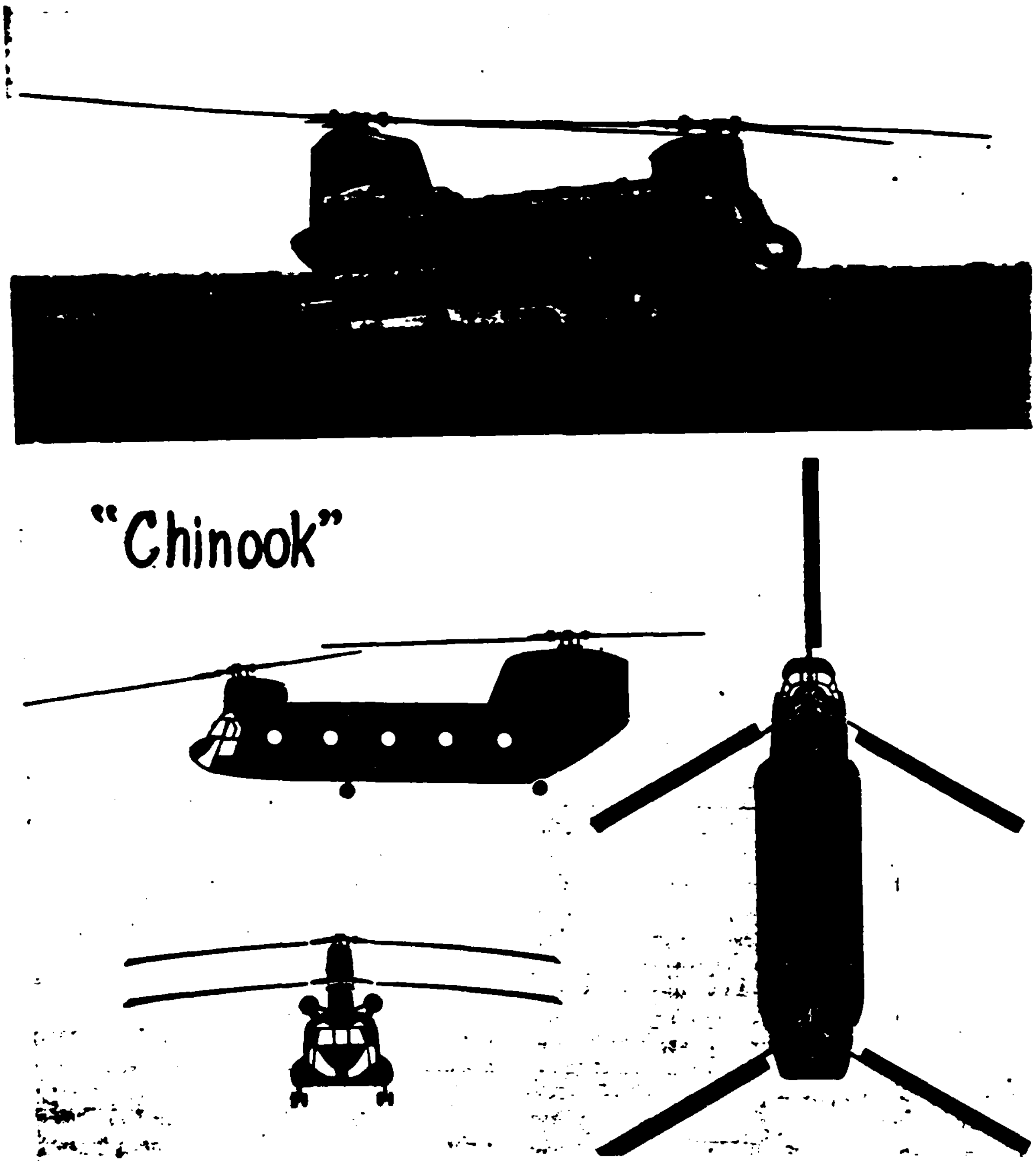

FIGURE 4

FLIGHT CONTROL HYDRAULIC SYSTEM (1/2)

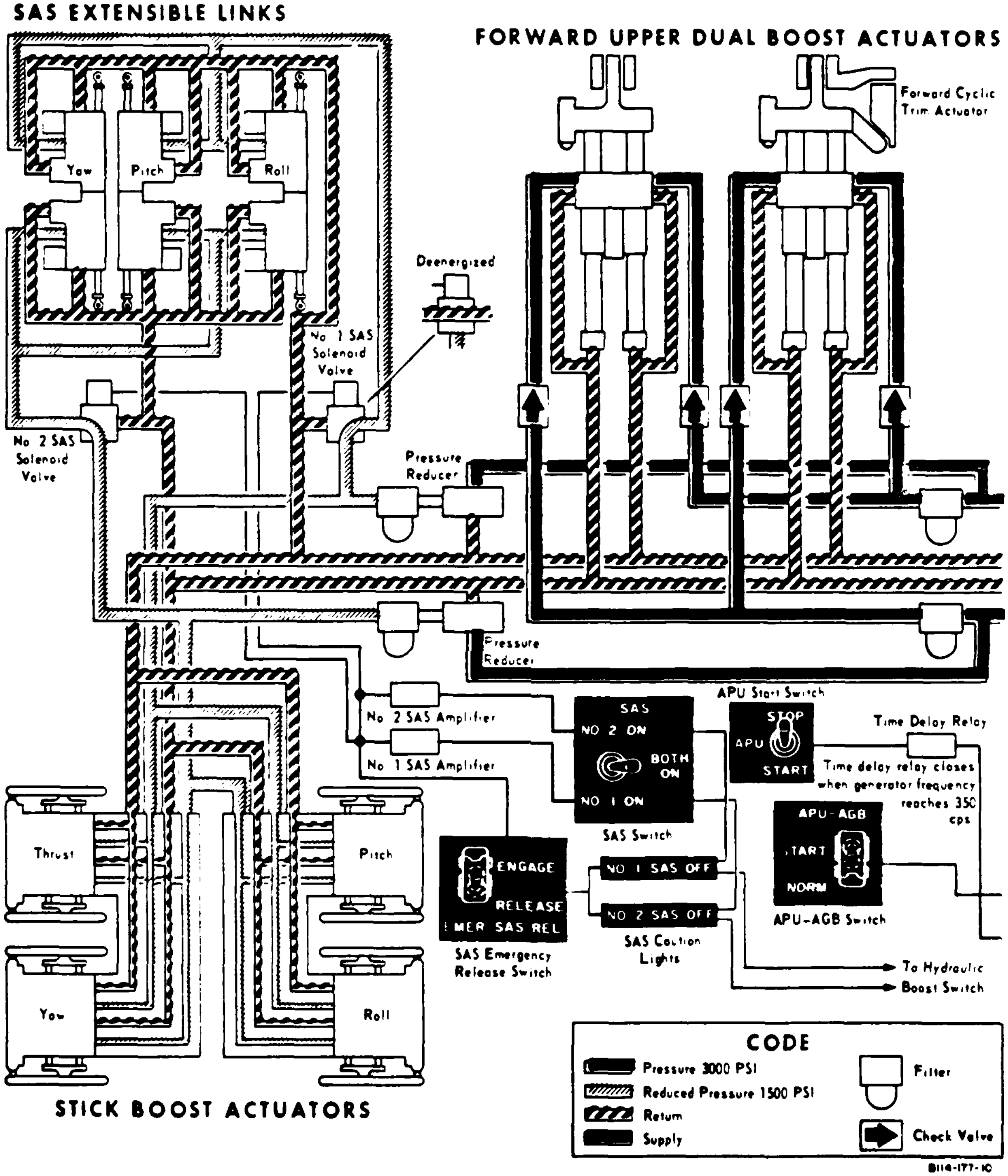

FIGURE 5

FLIGHT CONTROL HYDRAULIC SYSTEM (2/2)

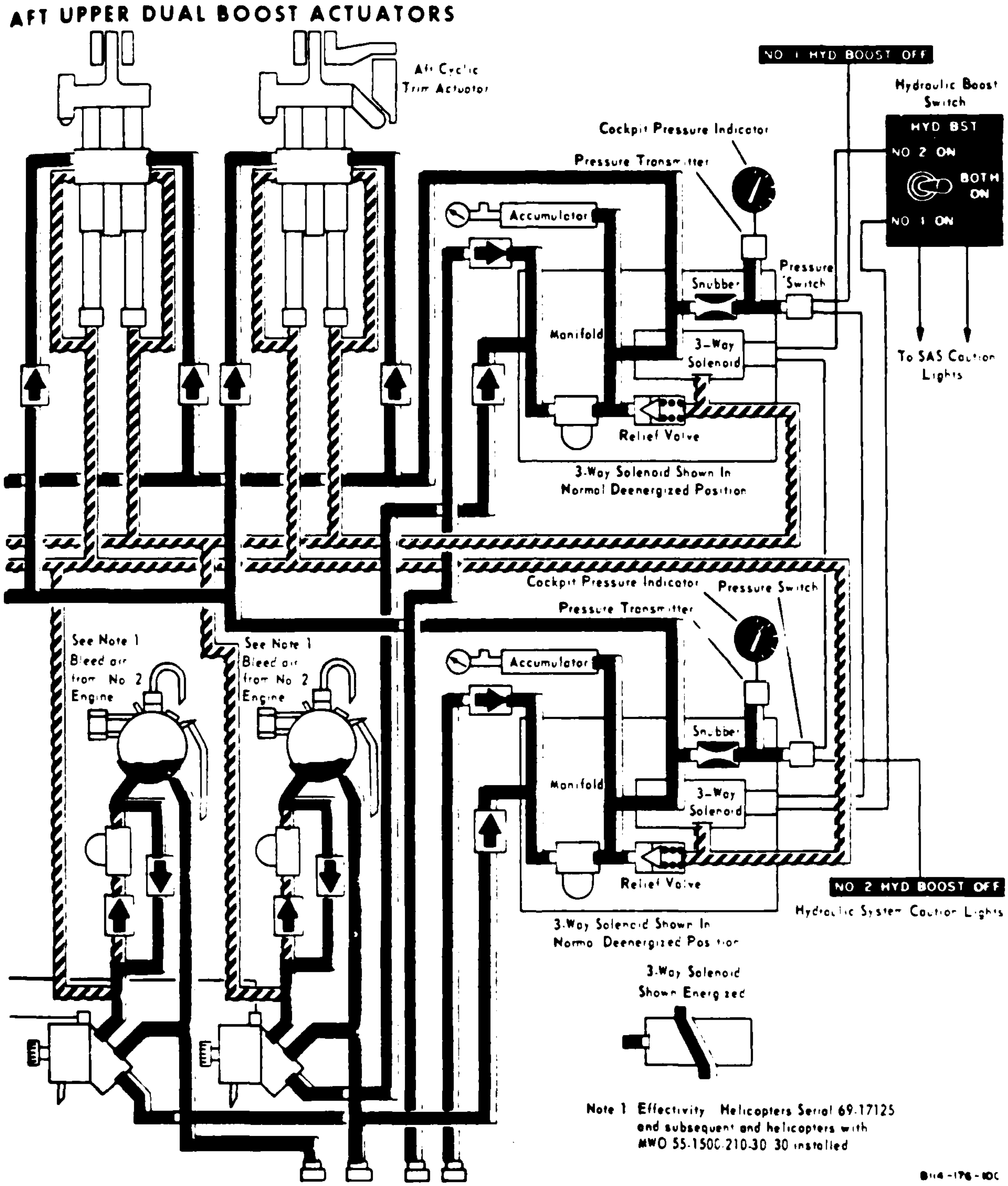

FIGURE 6

ACKNOWLEDGMENTS

Many thanks to Dave Handleman for his assistance throughout the term. He is the author of the expert system's inference engine.

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4. Duda, Richard O., Gasching, John G. "Knowledge-Based Expert Systems Come of Age," BYTE Publications Inc., September 1981, p. 238.

5. Joyce, Major General Robert M., "Aviation Unit and Aviation Intermediate Maintenance Manual: Army Model CH-47B Helicopter," U.S. Department of the Army, August 16, 1978.

6. Operation's Manual,"Army Model CH-47B and CH-47C Helicopters," Department of the Army, Washington, D.C., August 5, 1970.

7. Personal Consultant Software Package - Texas Instruments Inc., 1985

Appendix A

LIST OF PARAMETERS

Appendix A presents the list of parameters that are to be used in the present knowledge base. The basis for the rules are drawn from maintenance and operation manuals.

LIST OF PARAMETERS

SYMPTOMS:

PL - PRESSURE INDICATION IS LOW : (LESS THAN 2500 PSI)
PH - PRESSURE INDICATION IS HIGH : (GREATER THAN 3200 PSI)
PZ - PRESSURE INDICATION IS ZERO
PFL - PRESSURE INDICATION IS FLUCTUATING

P-450-550 - PRESSURE IS BETWEEN 450 AND 550 PSI AFTER APU START
NP-2500-3200 - NEW PRESSURE IS BETWEEN 2500 AND 3200 PSI
NP-EQ-P - NEW PRESSURE IS EQUAL TO PRESSURE
AGP-2500-3200 - ACCUMULATOR GAGE PRESSURE IS BETWEEN 2500 AND 3200 PSI

HBF-1CL-ON - HYD BOOST OFF SYSTEM 1 CAUTION LIGHT ON

PI1-L - PRESSURE INDICATOR 1 LOW
PI1-F - PRESSURE INDICATOR 1 FLUCTUATING
PI2-L - PRESSURE INDICATOR 2 LOW
PI2-F - PRESSURE INDICATOR 2 FLUCTUATING

IPS - INOPERATIVE PNEUMATIC SYSTEM

AGP-EQ-P - ACCUMULATOR GAGE PRESSURE EQUAL TO COCKPIT PRESSURE INDICATION
AGB-28 - TEMPERATURE OF HOSE FITTING AT PUMP PRESSURE PORT IS GREATER THAN TEMPERATURE OF HOSE FITTING AT PUMP CASE DRAIN PORT BY 28 DEGREES CELSIUS
BG-102 - TEMPERATURE OF HOSE FITTING AT PUMP CASE DRAIN PORT IS GREATER THAN 102 DEGREES CELSIUS
TC-GTE-TA - TEMPERATURE OF RETURN LINE TUBE ASSEMBLY AT FLIGHT CONTROL MANIFOLD IS GREATER THAN OR EQUAL TO TEMPERATURE OF HOSE FITTING AT PUMP PRESSURE PORT

TDA-COMPONENTX - TEMPERATURE DIFFERENTIAL BETWEEN INLET AND OUTLET PORT OF COMPONENT X IS ABNORMAL
TDA-PRV - COMPONENTX=PRESSURE REDUCE VALVE
TDA-FBA - COMPONENTX=FLIGHT BOOST ACCUMULATOR
TDA-FCP - COMPONENTX=FLIGHT CONTROL PUMP
TDA-HT - COMPONENTX=HYDRAULIC TANKS
TDA-PF - COMPONENTX=PRESSURE FILTER
TDA-RF - COMPONENTX=RETURN FILTER

TA-IN-SYS- TRAPPED AIR IN SYSTEM

AG-F - ACCUMULATOR GAGE FLUCTUATION

POSSIBLE DEVICE FAILURES/CORRECTIVE ACTIONS:

EC-FCP - ELECTRIC CIRCUIT TO FLIGHT CONTROL PUMP
SH-BO2 - SET HYDRAULIC BOOST 2 ON
FCM - FLIGHT CONTROL MANIFOLD
TA-AT-PT - TRAPPED AIR AT PRESSURE TRANSMITTER
PI - PRESSURE INDICATOR
PT - PRESSURE TRANSMITTER
FCP - FLIGHT CONTROL PUMP
FCM - FLIGHT CONTROL MANIFOLD
PRV - PRESSURE REDUCE VALVE
FBA - FLIGHT BOOST ACCUMULATOR
HT - HYDRAULIC TANK
PF - PRESSURE FILTER
RF - RETURN FILTER
L-FS-L - LOOSEN FLEXIBLE SUPPLY LINE TO PUMP
L-FBA-L - LOOSEN LINE TO FLIGHT BOOST ACCUMULATOR

GOAL:

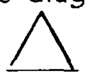
FAILURE-DETECTED - GOAL OF THE EXPERT SYSTEM: TO DETERMINE WHETHER THE FAILURE DEVICE HAS BEEN DEDUCED OR IF THERE INDEED IS A FAILURE

ALL-DEVICES-TESTED - TO DETERMINE WHETHER ALL DEVICES WERE TESTED

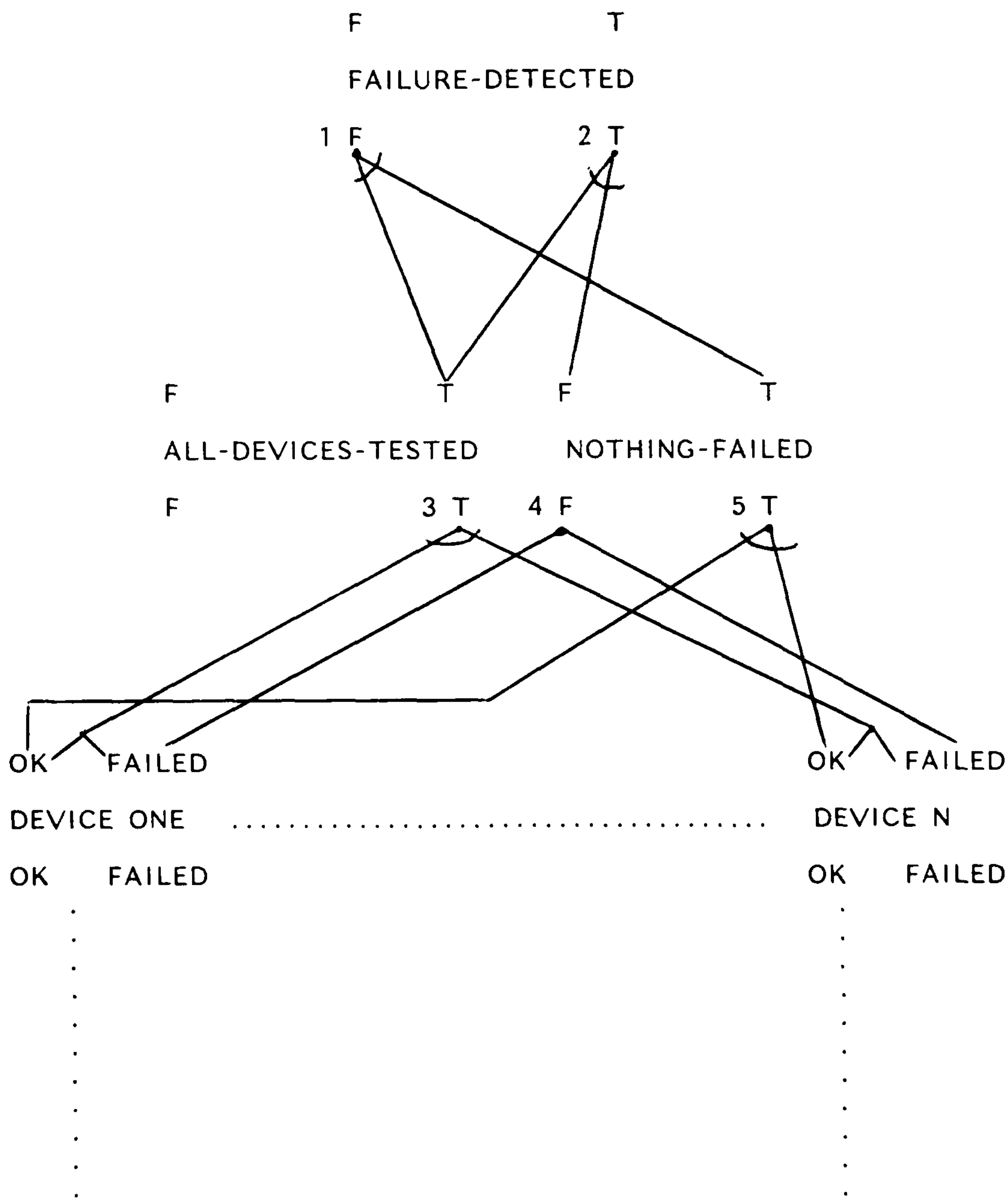
NOTHING-FAILED - TO DETERMINE WHETHER ANY DEVICES FAILED OR CORRECTIVE ACTIONS TAKEN

Appendix B

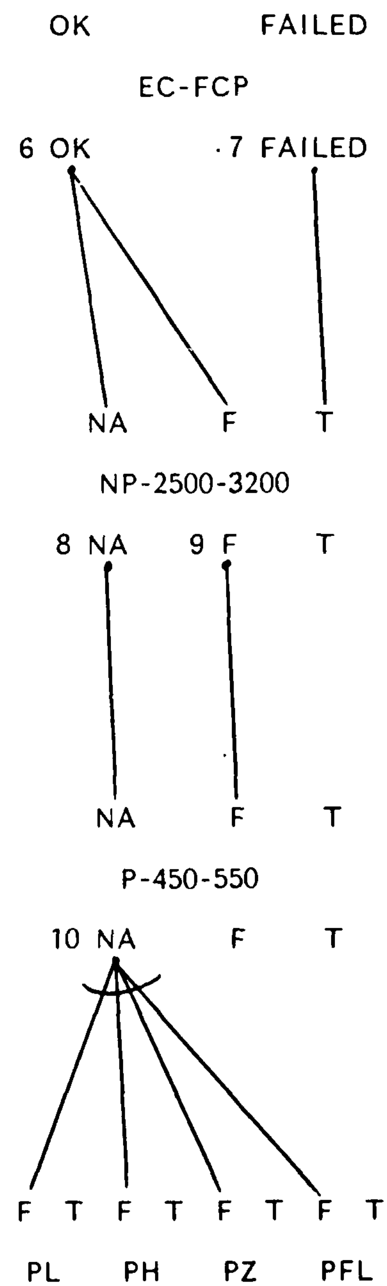
FAILURE DIAGNOSIS RULES

The expert system uses rules and a global data base to diagnose failures. Appendix B concentrates on the diagrammatical upward causal flow of the knowledge base. The symbol  symbolizes the **OR** function and the symbol  symbolizes the **AND** function. The value **NA** denotes NOT APPLICABLE. This is an alternative to the boolean values **TRUE** and **FALSE.** In addition, the inference engine should produce all possible device failures. The system should **NEVER** return an unknown value for a possible device failure. As an illustration of the use of the schematic diagrams, the English translation of RULE ONE is as follows: "*If all devices tested is true and nothing failed is true then failure detected is false*."

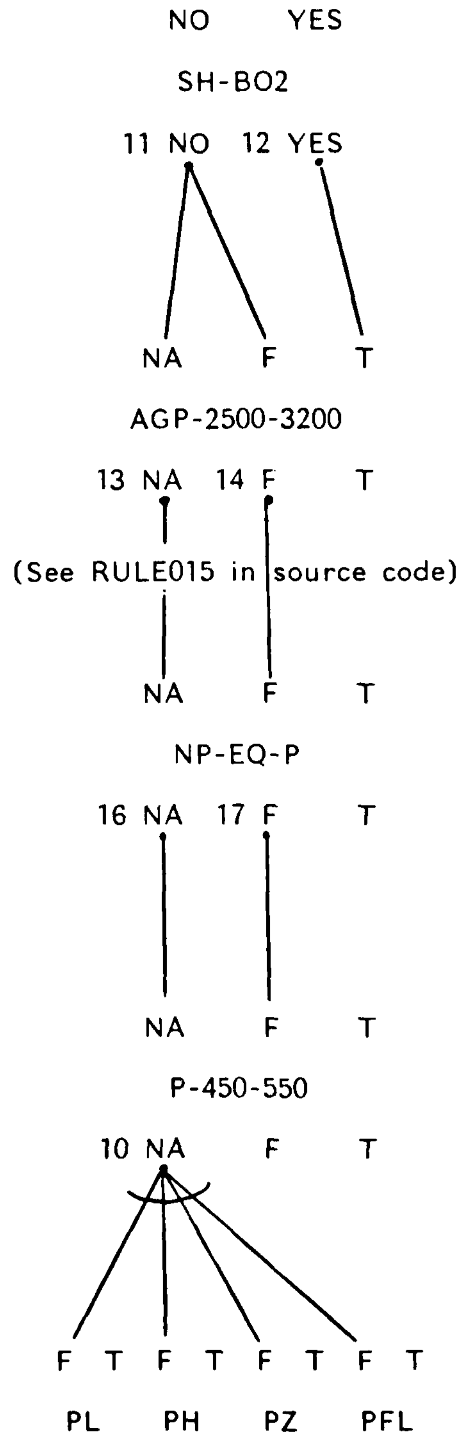
TOP LEVEL


F
T
FAILURE-DETECTED
1 F
2 T
F
T
F
T
ALL-DEVICES-TESTED
NOTHING-FAILED
F
3 T
4 F
5 T
OK
FAILED
DEVICE ONE
OK
FAILED
OK
FAILED
DEVICE N
OK
FAILED

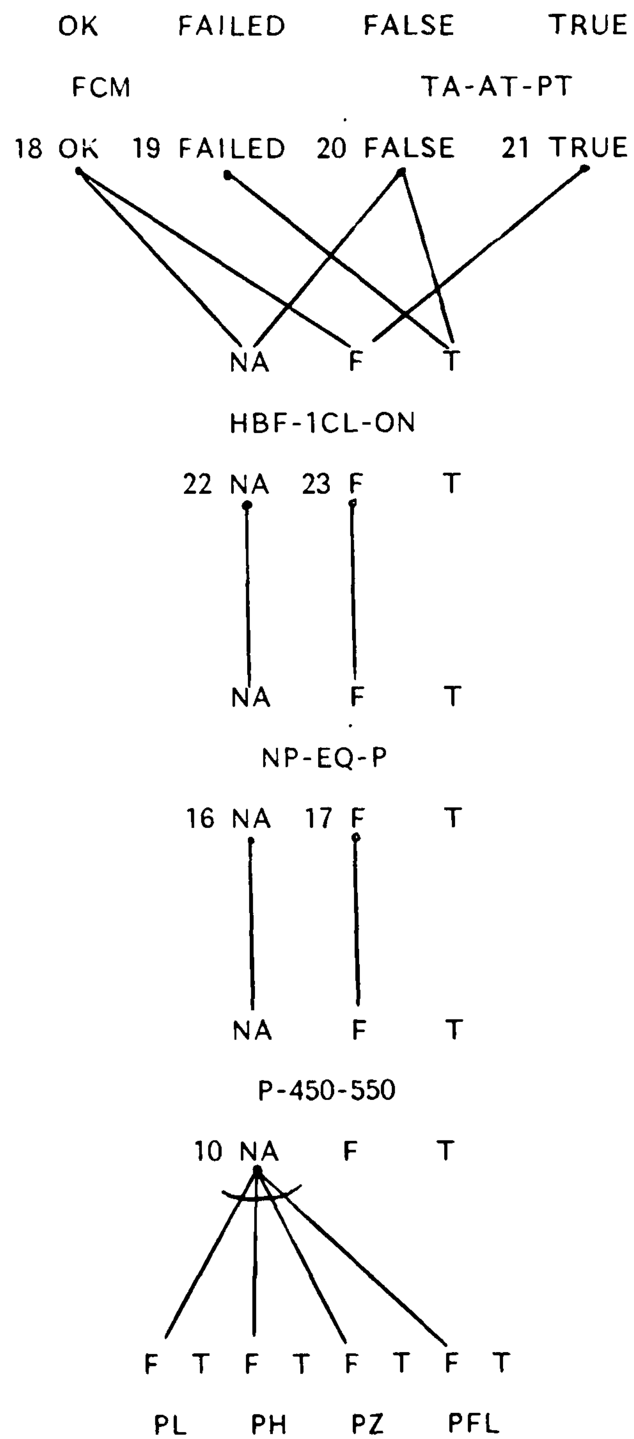
ELECTRIC CIRCUIT TO FLIGHT CONTROL PUMP



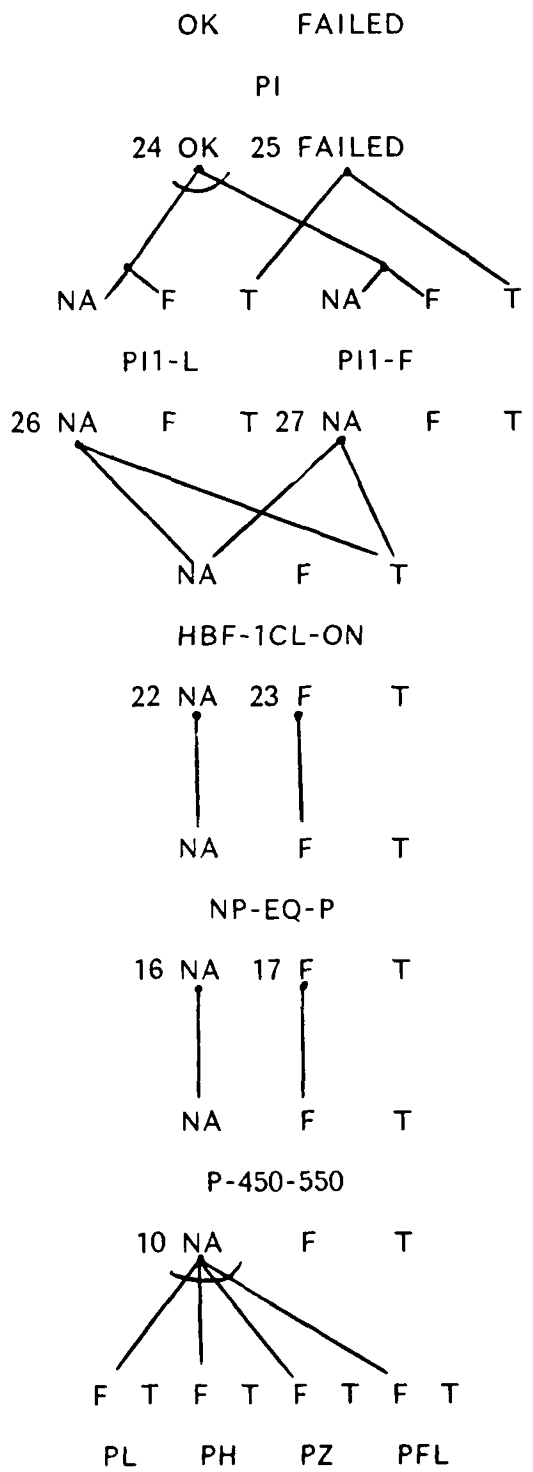
SET HYDRAULIC BOOST TWO ON



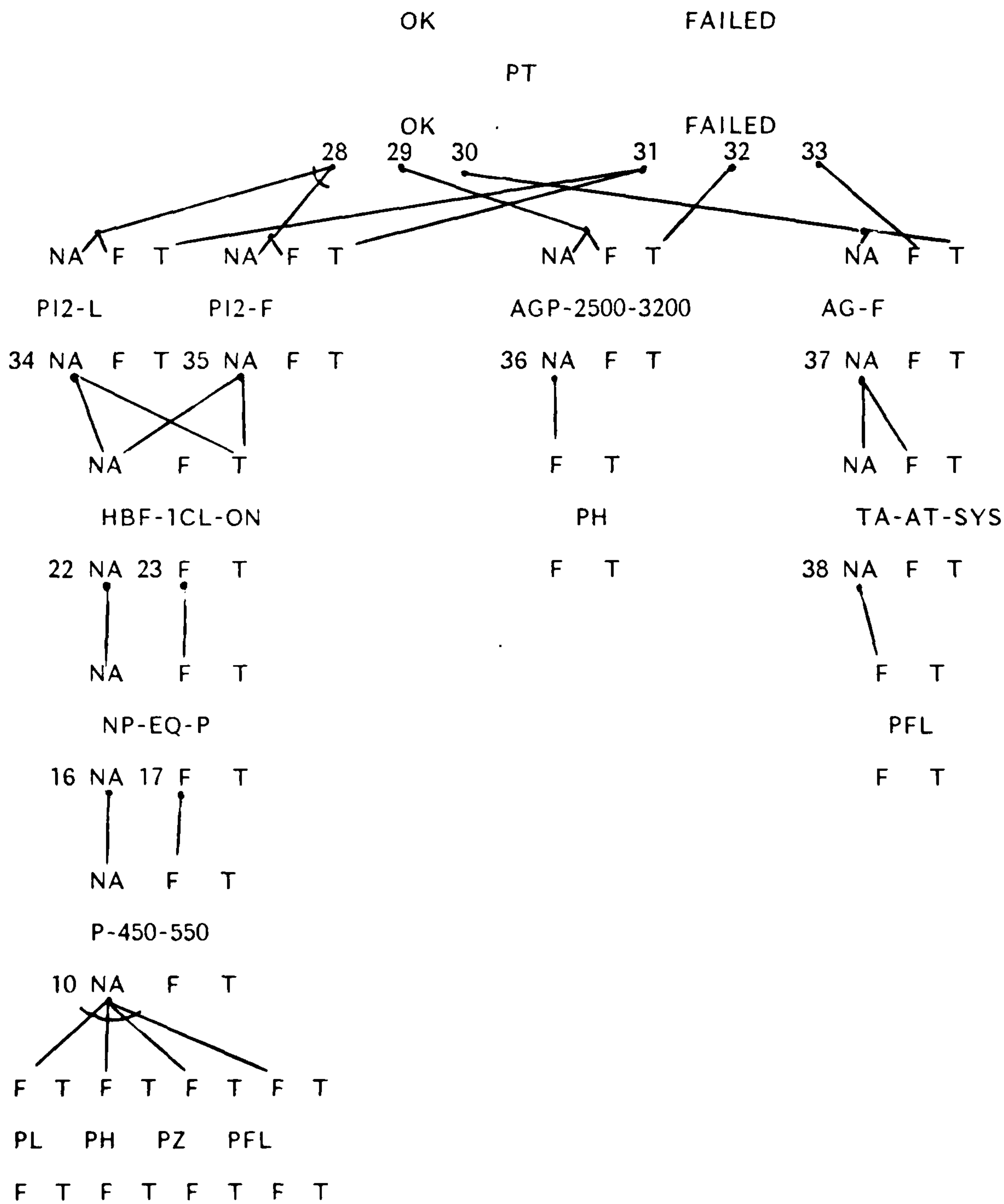
FLIGHT CONTROL MANIFOLD & TRAPPED AIR AT PRESSURE TRANSMITTOR



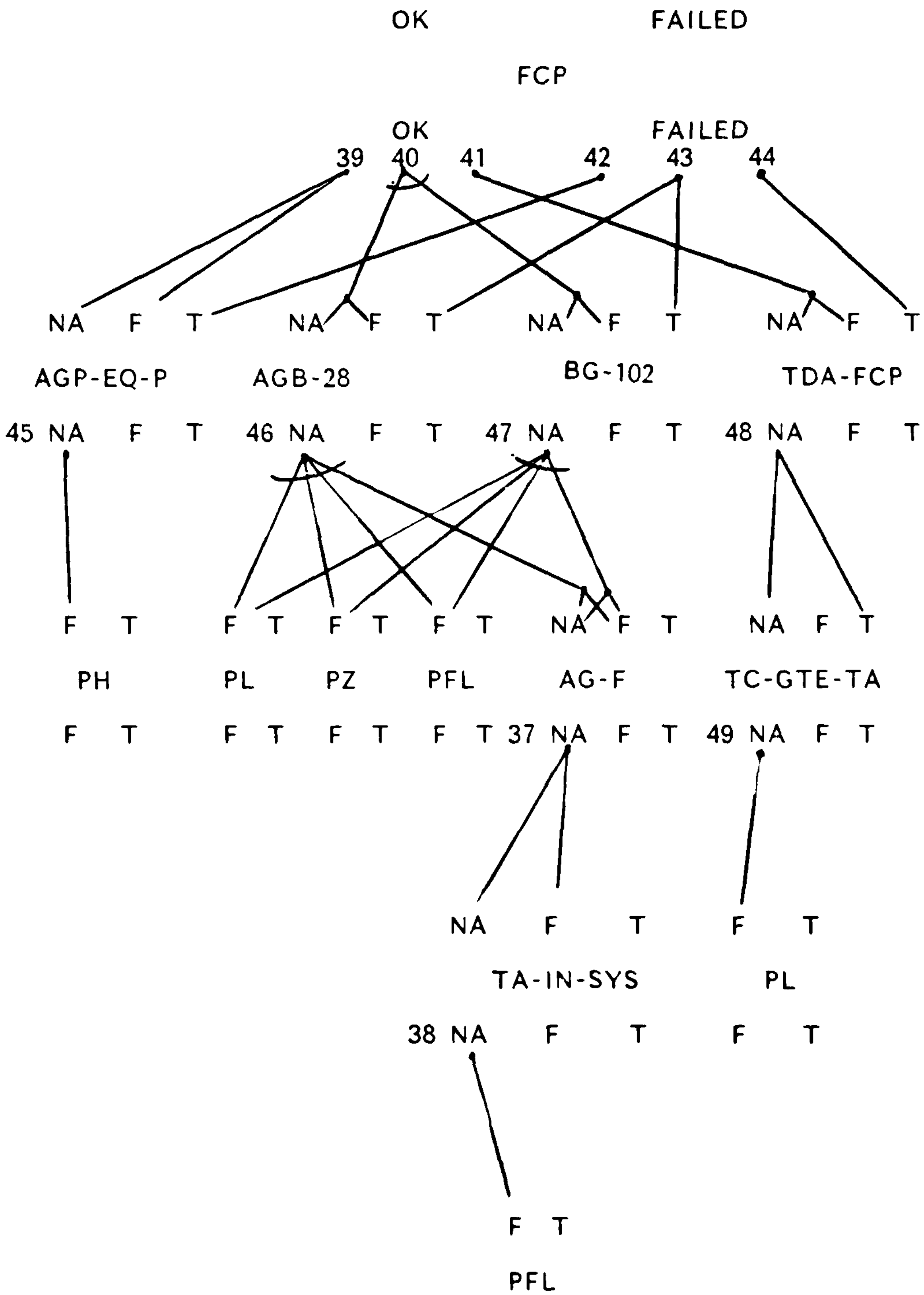
PRESSURE INDICATOR



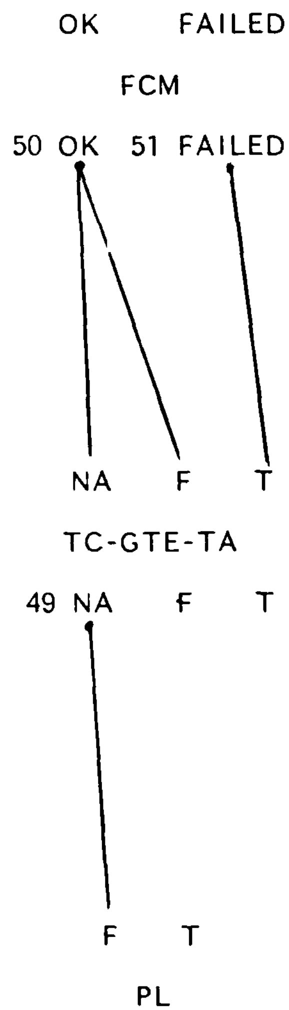
PRESSURE TRANSMITTOR



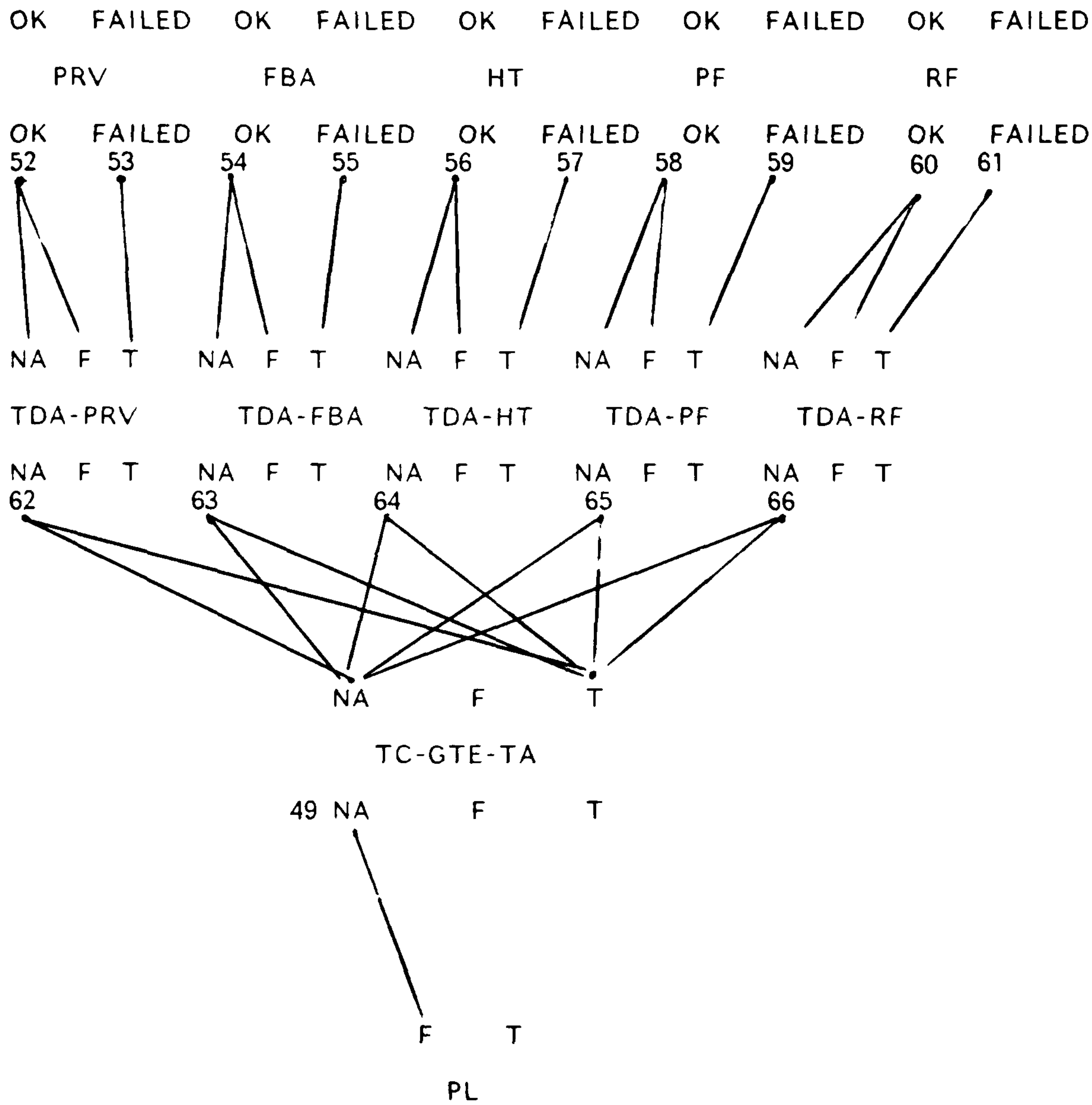
FLIGHT CONTROL PUMP



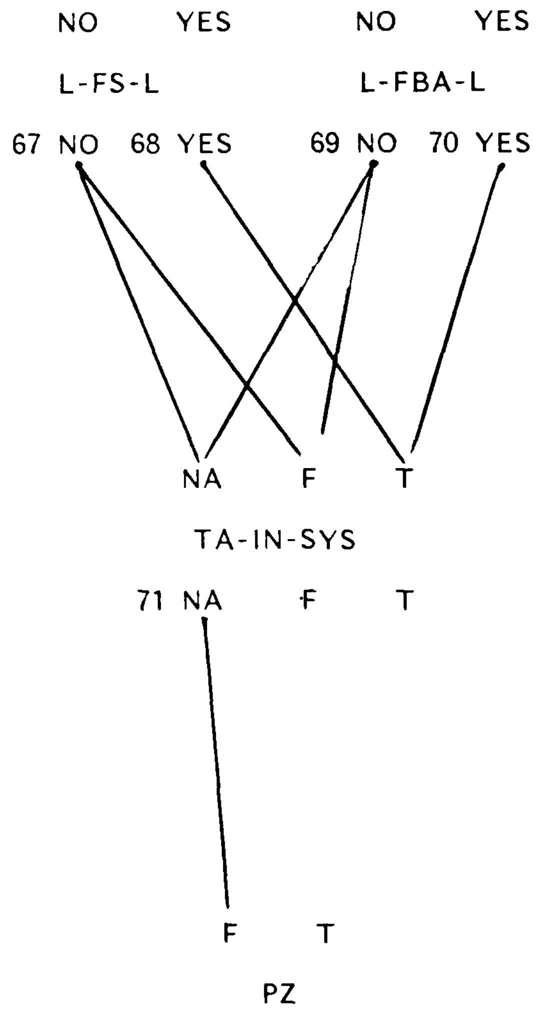
FLIGHT CONTROL MANIFOLD



COMPONENT LEAKAGES



LOOSEN LINES



Appendix C

KNOWLEDGE BASE SOURCE CODE

The following knowledge base is coded in IQLISP. As of December 31, 1985 there are 41 parameters and 71 rules. It is listed in subdirectory CLOH and under filename LOHKB.LSP.

```
(FLOAD "EXPSHELL")


(MSG 'CR "Reading Knowledge Base")


~ #####   KNOWLEDGE BASE PARAMETER GROUPS   ############################

~                                Christopher J. Loh
~                                Laboratory for Control & Automation
~                                Knowledge Base / Parameters
~                                CH-47 Flight Control Hydraulic System
~                                Fall 1985


~ PARAMETER GROUP PROPERTIES
~   system-supplied:
~     used-by          specifies rules with this parameter in their premise
~     contained-in     specifies rules with this parameter in their action
~                      but that do not assign a value to the parameter
~     updated-by       specifies rules that conclude a value for this parameter
~                      in their action
~   user-supplied:
~     trans            English translation (definition)
~     expect
~     initial-value
~     never-ask        If a parameter value is unknown, it cannot be inferred
~                      with rules, and has never-ask TRUE, then the search fails
~     prompt
~     askfirst
~     justification


 (INTERN-SYMBOL-GROUP   *PARAMETER-GROUP*

 ~ Top Level Goal

   (FAILURE-DETECTED
     (TRANS '(the failure is detected))
     (EXPECT '(TRUE FALSE))
     (NEVER-ASK T))

   (ALL-DEVICES-TESTED
     (TRANS '(all devices are tested))
     (EXPECT '(TRUE FALSE))
     (NEVER-ASK T))

   (NOTHING-FAILED
     (TRANS '(nothing has failed))
     (EXPECT '(TRUE FALSE))
```

```
   (NEVER-ASK T))

~ I ssible Device Failures / Corrective Actions

  (EC-FCP
   (TRANS '(electric circuit to hydraulic flight control pump))
   (EXPECT '(OK FAILED))
   (NEVER-ASK NIL))

  (SH-BO2
   (TRANS '(should set hydraulic boost 2 on))
   (EXPECT '(YES NO))
   (NEVER-ASK NIL))

  (FCM
   (TRANS '(flight control manifold))
   (EXPECT '(OK FAILED))
   (NEVER-ASK NIL))

  (TA-AT-PT
   (TRANS '(trapped air at pressure transmitter))
   (EXPECT '(TRUE FALSE))
   (NEVER-ASK NIL))

  (PI
   (TRANS '(pressure indicator))
   (EXPECT '(OK FAILED))
   (NEVER-ASK NIL))

  (PT
   (TRANS '(pressure transmitter))
   (EXPECT '(OK FAILED))
   (NEVER-ASK NIL))

  (FCP
   (TRANS '(flight control pump))
   (EXPECT '(OK FAILED))
   (NEVER-ASK NIL))

  (FCM
   (TRANS '(flight control manifold))
   (EXPECT '(OK FAILED))
   (NEVER-ASK NIL))

  (PRV
   (TRANS '(pressure reduce valve))
   (EXPECT '(OK FAILED))
   (NEVER-ASK NIL))

  (FBA
   (TRANS '(flight boost accumulator))
   (EXPECT '(OK FAILED))
   (NEVER-ASK NIL))

  (HT
   (TRANS '(hydraulic tank))
   (EXPECT '(OK FAILED))
```

```
    (NEVER-ASK NIL))

  (PF
    (TRANS '(pressure filter))
    (EXPECT '(OK FAILED))
    (NEVER-ASK NIL))

  (RF
    (TRANS '(return filter))
    (EXPECT '(OK FAILED))
    (NEVER-ASK NIL))

  (L-FS-L
    (TRANS '(should loosen flexible supply line to flight control pump))
    (EXPECT '(YES NO))
    (NEVER-ASK NIL))

  (L-FBA-L
    (TRANS '(should loosen line to flight boost accumulator))
    (EXPECT '(YES NO))
    (NEVER-ASK NIL))


~ Symptoms Which Lead to Device Failures

  (PI1-L
    (TRANS '(pressure indicator 1 is low))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (PI1-F
    (TRANS '(pressure indicator 1 is fluctuating))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (PI2-L
    (TRANS '(pressure indicator 2 is low))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (PI2-F
    (TRANS '(pressure indicator 2 is fluctuating))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (AGP-2500-3200
    (TRANS '(accumulator gage pressure between 2500 and 3200
             with system depressurized))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (HBF-1CL-ON
    (TRANS '(HYD BOOST OFF system 1 caution light on))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (TDA-PRV
    (TRANS '(temperature differential between inlet and outlet
```

```
            of pressure reduce valve is abnormal))
  (EXPECT '(TRUE FALSE NA))
  (NEVER-ASK NIL))

(TDA-FBA
  (TRANS '(temperature differential between inlet and outlet
            of flight boost accumulator is abnormal))
  (EXPECT '(TRUE FALSE NA))
  (NEVER-ASK NIL))

(TDA-FCP
  (TRANS '(temperature differential between inlet and outlet
            of flight control pump is abnormal))
  (EXPECT '(TRUE FALSE NA))
  (NEVER-ASK NIL))

(TDA-HT
  (TRANS '(temperature differential between inlet and outlet
            of hydraulic tank is abnormal))
  (EXPECT '(TRUE FALSE NA))
  (NEVER-ASK NIL))

(TDA-PF
  (TRANS '(temperature differential between inlet and outlet
            of pressure filter is abnormal))
  (EXPECT '(TRUE FALSE NA))
  (NEVER-ASK NIL))

(TDA-RF
  (TRANS '(temperature differential between inlet and outlet
            of return filter is abnormal))
  (EXPECT '(TRUE FALSE NA))
  (NEVER-ASK NIL))

(AGP-EQ-P
  (TRANS '(accumulator gage pressure equal to cockpit
            pressure indication))
  (EXPECT '(TRUE FALSE NA))
  (NEVER-ASK NIL))

(AGB-28
  (TRANS '(temperature of hose fitting at pump pressure port
            is greater than temperature of hose fitting at pump
            case drain port by 28 degrees celsius))
  (EXPECT '(TRUE FALSE NA))
  (NEVER-ASK NIL))

(BG-102
  (TRANS '(temperature of hose fitting at pump case drain port
            is greater than 102 degrees celsius))
  (EXPECT '(TRUE FALSE NA))
  (NEVER-ASK NIL))

(TC-GTE-TA
  (TRANS '(temperature of return line tube assembly at flight
            control manifold is greater than or equal to temperature
            of hose fitting at pump pressure port))
  (EXPECT '(TRUE FALSE NA))
```

```
    (NEVER-ASK NIL))

  (NP-2500-3200
    (TRANS '(new pressure is between 2500 and 3200 psi
             after electric circuit is disconnected))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (NP-EQ-P
    (TRANS '(new pressure approximately equal to old pressure
             after electric circuit is disconnected))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (IPS
    (TRANS '(inoperative pneumatic system))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (P-450-550
    (TRANS '(old pressure is between 450 and 550 psi after apu start))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (AG-F
    (TRANS '(accumulator gage fluctuation))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (TA-IN-SYS
    (TRANS '(trapped air at system))
    (EXPECT '(TRUE FALSE NA))
    (NEVER-ASK NIL))

  (PL
    (TRANS '(pressure indication is low - less than 2500 psi))
    (EXPECT '(TRUE FALSE))
    (NEVER-ASK NIL))

  (PH
    (TRANS '(pressure indication is high - greater than 3200 psi))
    (EXPECT '(TRUE FALSE))
    (NEVER-ASK NIL))

  (PZ
    (TRANS '(pressure indication is zero))
    (EXPECT '(TRUE FALSE))
    (NEVER-ASK NIL))

  (PFL
    (TRANS '(pressure indication is fluctuating))
    (EXPECT '(TRUE FALSE))
    (NEVER-ASK NIL)))


~ #####   KNOWLEDGE BASE RULE GROUPS   ###############################
```

```
~ RULE GROUP PROPERTIES
~    trans
~    premise
~    action


(INTERN-SYMBOL-GROUP   *RULE-GROUP*

  (RULE001
    (TRANS
      '(if   all devices tested is true and nothing failed is also true
        then failure detected is false))
    (PREMISE
      '(AND ($EQ ALL-DEVICES-TESTED 'TRUE) ($EQ NOTHING-FAILED 'TRUE)))
    (ACTION
      '($SETQ FAILURE-DETECTED 'FALSE)))

  (RULE002
    (TRANS
      '(if   all devices tested is true and nothing failed is false
        then failure detected is true))
    (PREMISE
      '(AND ($EQ ALL-DEVICES-TESTED 'TRUE) ($EQ NOTHING-FAILED 'FALSE)))
    (ACTION
      '($SETQ FAILURE-DETECTED 'TRUE)))

  (RULE003
    (TRANS
      '(if    all devices are not unknown
        then  all devices tested is true))
    (PREMISE
      '(AND (NOT ($EQ EC-FCP 'FOO))
            (NOT ($EQ SH-BO2 'FOO))
            (NOT ($EQ FCM 'FOO))
            (NOT ($EQ TA-AT-PT 'FOO))
            (NOT ($EQ PI 'FOO))
            (NOT ($EQ PT 'FOO))
            (NOT ($EQ FCP 'FOO))
            (NOT ($EQ FCM 'FOO))
            (NOT ($EQ PRV 'FOO))
            (NOT ($EQ FBA 'FOO))
            (NOT ($EQ HT 'FOO))
            (NOT ($EQ PF 'FOO))
            (NOT ($EQ RF 'FOO))
            (NOT ($EQ L-FS-L 'FOO))
            (NOT ($EQ L-FBA-L 'FOO))))
    (ACTION
      '($SETQ ALL-DEVICES-TESTED 'TRUE)))

  (RULE004
    (TRANS
      '(if    any device failed or any corrective action taken
        then  nothing failed or no corrective action taken is false))
```

```
    (PREMISE
      '(OR ($EQ EC-FCP 'FAILED)
           ($EQ SH-BO2 'YES)
           ($EQ FCM 'FAILED)
           ($EQ TA-AT-PT 'TRUE)
           ($EQ PI 'FAILED)
           ($EQ PT 'FAILED)
           ($EQ FCP 'FAILED)
           ($EQ FCM 'FAILED)
           ($EQ PRV 'FAILED)
           ($EQ FBA 'FAILED)
           ($EQ HT 'FAILED)
           ($EQ PF 'FAILED)
           ($EQ RF 'FAILED)
           ($EQ L-FS-L 'YES)
           ($EQ L-FBA-L 'YES)))
    (ACTION
      '($SETQ NOTHING-FAILED 'FALSE)))

  (RULE005
    (TRANS
      '(if    all devices are ok
        then  all nothing failed is true))
    (PREMISE
      '(AND ($EQ EC-FCP 'OK)
            ($EQ SH-BO2 'NO)
            ($EQ FCM 'OK)
            ($EQ TA-AT-PT 'FALSE)
            ($EQ PI 'OK)
            ($EQ PT 'OK)
            ($EQ FCP 'OK)
            ($EQ FCM 'OK)
            ($EQ PRV 'OK)
            ($EQ FBA 'OK)
            ($EQ HT 'OK)
            ($EQ PF 'OK)
            ($EQ RF 'OK)
            ($EQ L-FS-L 'NO)
            ($EQ L-FBA-L 'NO)))
    (ACTION
      '($SETQ NOTHING-FAILED 'TRUE)))

  (RULE006
    (TRANS
      '(if   new pressure after electric circuit is disconnected is
             between 2500 and 3200 psi is not applicable or false
        then electric circuit to flight control pump is ok))
    (PREMISE
      '(OR ($EQ NP-2500-3200 'NA) ($EQ NP-2500-3200 'FALSE)))
    (ACTION
      '($SETQ EC-FCP 'OK)))

  (RULE007
    (TRANS
      '(if   new pressure after electric circuit is disconnected is
             between 2500 and 3200 psi is true
        then electric circuit to flight control pump is failed))
    (PREMISE
```

```
    '($EQ NP-2500-3200 'TRUE))
   (ACTION
    '($SETQ EC-FCP 'FAILED)))

 (RULE008
   (TRANS
    '(if   pressure is between 450 and 550 psi after auxiliary power
           unit start is not applicable
      then new pressure after electric circuit is disconnected is
           between 2500 and 3200 psi is not applicable))
   (PREMISE
    '($EQ P-450-550 'NA))
   (ACTION
    '($SETQ NP-2500-3200 'NA)))

 (RULE009
   (TRANS
    '(if   pressure is between 450 and 550 psi after auxiliary power
           unit start is false
      then new pressure after electric circuit is disconnected is
           between 2500 and 3200 psi is false))
   (PREMISE
    '($EQ P-450-550 'FALSE))
   (ACTION
    '($SETQ NP-2500-3200 'FALSE)))

 (RULE010
   (TRANS
    '(if   pressure indication is low is false
       and pressure indication is high is false
       and pressure indication is zero is false
       and pressure indication is fluctuating is false
      then pressure is between 450 and 550 psi after auxiliary power
           unit start is not applicable))
   (PREMISE
    '(AND ($EQ PL 'FALSE) ($EQ PH 'FALSE)
          ($EQ PZ 'FALSE) ($EQ PFL 'FALSE)))
   (ACTION
    '($SETQ P-450-550 'NA)))

 (RULE011
   (TRANS
    '(if   accumulator gage pressure with system depressurized is
           between 2500 and 3200 psi is not applicable or false
      then do not set hydraulic boost 2 switch on))
   (PREMISE
    '(OR ($EQ AGP-2500-3200 'NA) ($EQ AGP-2500-3200 'FALSE)))
   (ACTION
    '($SETQ SH-BO2 'NO)))

 (RULE012
   (TRANS
    '(if   accumulator gage pressure with system depressurized is
           between 2500 and 3200 psi is true
      then do set hydraulic boost 2 switch on))
   (PREMISE
    '($EQ AGP-2500-3200 'TRUE))
   (ACTION
```

```
      '($SETQ SH-BO2 'YES)))

   (RULE013
     (TRANS
      '(if   new pressure after electric circuit is disconnected is
             approximately equal to old pressure is not applicable
        then accumulator gage pressure with system depressurized is
             between 2500 and 3200 psi is not applicable))
     (PREMISE
      '($EQ NP-EQ-P 'NA))
     (ACTION
      '($SETQ AGP-2500-3200 'NA)))

   (RULE014
     (TRANS
      '(if   new pressure after electric circuit is disconnected is
             approximately equal to old pressure is false
        then accumulator gage pressure with system depressurized is
             between 2500 and 3200 psi is false))
     (PREMISE
      '($EQ NP-EQ-P 'FALSE))
     (ACTION
      '($SETQ AGP-2500-3200 'FALSE)))

~ Rule 015 is to prevent search up NP-EQ-P if NP-2500-3200 is true.
~ If second parameter is true, then first parameter must be false.

   (RULE015
     (TRANS
      '(if   new pressure after electric circuit is disconnected is
             between 2500 and 3200 psi is true
        then new pressure after electric circuit is disconnected is
             approximately equal to old pressure is false))
     (PREMISE
      '($EQ NP-2500-3200 'TRUE))
     (ACTION
      '($SETQ NP-EQ-P 'FALSE)))


   (RULE016
     (TRANS
      '(if   pressure after auxiliary power unit start is between 450
             and 550 psi is not applicable
        then new pressure after electric circuit is disconnected is
             approximately equal to old pressure is not applicable))
     (PREMISE
      '($EQ P-450-550 'NA))
     (ACTION
      '($SETQ NP-EQ-P 'NA)))

   (RULE017
     (TRANS
      '(if   pressure after auxiliary power unit start is between 450
             and 550 psi is not false
        then new pressure after electric circuit is disconnected is
             approximately equal to old pressure is false))
     (PREMISE
      '($EQ P-450-550 'FALSE))
```

```
    (ACTION
      '($SETQ NP-EQ-P 'FALSE)))

  (RULE018
    (TRANS
      '(if   hydraulic boost off caution light on is not applicable
             or false
        then flight control manifold is ok))
    (PREMISE
      '(OR ($EQ HBF-1CL-ON 'NA) ($EQ HBF-1CL-ON 'FALSE)))
    (ACTION
      '($SETQ FCM 'OK)))

  (RULE019
    (TRANS
      '(if   hydraulic boost off caution light on is true
        then flight control manifold is failed))
    (PREMISE
      '($EQ HBF-1CL-ON 'TRUE))
    (ACTION
      '($SETQ FCM 'FAILED)))

  (RULE020
    (TRANS
      '(if   hydraulic boost off caution light on is not applicable
             or true
        then trapped air at pressure transmittor is false))
    (PREMISE
      '(OR ($EQ HBF-1CL-ON 'NA) ($EQ HBF-1CL-ON 'TRUE)))
    (ACTION
      '($SETQ TA-AT-PT 'FALSE)))

  (RULE021
    (TRANS
      '(if   hydraulic boost off caution light on is false
        then trapped air at pressure transmittor is true))
    (PREMISE
      '($EQ HBF-1CL-ON 'FALSE))
    (ACTION
      '($SETQ TA-AT-PT 'TRUE)))

  (RULE022
    (TRANS
      '(if   new pressure after electric circuit is disconnected is
             approximately equal to old pressure is not applicable
        then hydraulic boost off caution light on is not applicable))
    (PREMISE
      '($EQ NP-EQ-P 'NA))
    (ACTION
      '($SETQ HBF-1CL-ON 'NA)))

  (RULE023
    (TRANS
      '(if   new pressure after electric circuit is disconnected is
             approximately equal to old pressure is false
        then hydraulic boost off caution light on is false))
    (PREMISE
      '($EQ NP-EQ-P 'FALSE))
```

```
    (ACTION
      '($SETQ HBF-1CL-ON 'FALSE)))

  (RULE024
    (TRANS
      '(if    pressure indicator one is not low or not applicable
          and pressure indicator one is not fluctuating or not applicable
         then pressure indicator is ok))
    (PREMISE
      '(AND (OR ($EQ PI1-L 'NA) ($EQ PI1-L 'FALSE))
            (OR ($EQ PI1-F 'NA) ($EQ PI1-F 'FALSE))))
    (ACTION
      '($SETQ PI 'OK)))

  (RULE025
    (TRANS
      '(if    pressure indicator one is low
          or  pressure indicator one is fluctuating
         then pressure indicator is failed))
    (PREMISE
      '(OR ($EQ PI1-L 'TRUE) ($EQ PI1-F 'TRUE)))
    (ACTION
      '($SETQ PI 'FAILED)))

  (RULE026
    (TRANS
      '(if    hydraulic boost off caution light on is not applicable or
              true
         then pressure indicator 1 is low is not applicable))
    (PREMISE
      '(OR ($EQ HBF-1CL-ON 'NA) ($EQ HBF-1CL-ON 'TRUE)))
    (ACTION
      '($SETQ PI1-L 'NA)))

  (RULE027
    (TRANS
      '(if    hydraulic boost off caution light on is not applicable or
              true
         then pressure indicator 1 is fluctuating is not applicable))
    (PREMISE
      '(OR ($EQ HBF-1CL-ON 'NA) ($EQ HBF-1CL-ON 'TRUE)))
    (ACTION
      '($SETQ PI1-F 'NA)))

  (RULE028
    (TRANS
      '(if    pressure indicator two is not low or not applicable
          and pressure indicator two is not fluctuating or not applicable
         then pressure transmittor is ok))
    (PREMISE
      '(AND (OR ($EQ PI2-L 'NA) ($EQ PI2-L 'FALSE))
            (OR ($EQ PI2-F 'NA) ($EQ PI2-F 'FALSE))))
    (ACTION
      '($SETQ PT 'OK)))

  (RULE029
    (TRANS
      '(if    accumulator gage pressure is between 2500 and 3200 psi with
```

```
              system depressurized is not applicable or false
         then pressure transmittor is ok))
    (PREMISE
      '(OR ($EQ AGP-2500-3200 'NA) ($EQ AGP-2500-3200 'FALSE)))
    (ACTION
      '($SETQ PT 'OK)))

  (RULE030
    (TRANS
      '(if    accumulator gage is fluctuating is not applicable or true
         then pressure transmittor is ok))
    (PREMISE
      '(OR ($EQ AG-F 'NA) ($EQ AG-F 'TRUE)))
    (ACTION
      '($SETQ PT 'OK)))

  (RULE031
    (TRANS
      '(if    pressure indicator 2 is low or fluctuating is true
         then pressure transmittor is failed))
    (PREMISE
      '(OR ($EQ PI2-L 'TRUE) ($EQ PI2-F 'TRUE)))
    (ACTION
      '($SETQ PT 'FAILED)))

  (RULE032
    (TRANS
      '(if    accumulator gage pressure is between 2500 and 3200 psi with
              system depressurized is true
         then pressure transmittor is failed))
    (PREMISE
      '($EQ AGP-2500-3200 'TRUE))
    (ACTION
      '($SETQ PT 'FAILED)))

  (RULE033
    (TRANS
      '(if    accumulator gage pressure is fluctuating is false
         then pressure transmittor is failed))
    (PREMISE
      '($EQ AG-F 'FALSE))
    (ACTION
      '($SETQ PT 'FAILED)))

  (RULE034
    (TRANS
      '(if    hydraulic boost off caution light on is not applicable or
              true
         then pressure indicator 2 is low is not applicable))
    (PREMISE
      '(OR ($EQ HBF-1CL-ON 'NA) ($EQ HBF-1CL-ON 'TRUE)))
    (ACTION
      '($SETQ PI2-L 'NA)))

  (RULE035
    (TRANS
      '(if    hydraulic boost off caution light on is not applicable or
              true
```

```
      then pressure indicator 2 is fluctuating is not applicable))
  (PREMISE
   '(OR ($EQ HBF-1CL-ON 'NA) ($EQ HBF-1CL-ON 'TRUE)))
  (ACTION
   '($SETQ PI2-F 'NA)))

(RULE036
  (TRANS
   '(if   pressure indication is high is false
     then accumulator gage pressure is between 2500 and 3200 psi
          is not applicable))
  (PREMISE
   '($EQ PH 'FALSE))
  (ACTION
   '($SETQ AGP-2500-3200 'NA)))

(RULE037
  (TRANS
   '(if   trapped air at system is not applicable or false
     then accumulator gage pressure is fluctuating is not applicable))
  (PREMISE
   '(OR ($EQ TA-IN-SYS 'NA) ($EQ TA-AT-SYS 'FALSE)))
  (ACTION
   '($SETQ AG-F 'NA)))

(RULE038
  (TRANS
   '(if   pressure indication is fluctuatingis false
     then trapped air at system is not applicable))
  (PREMISE
   '($EQ PFL 'FALSE))
  (ACTION
   '($SETQ TA-IN-SYS 'NA)))

(RULE039
  (TRANS
   '(if   accumulator gage pressure indication is equal to cockpit
          pressure indication is not applicable or false
     then flight control pump is ok))
  (PREMISE
   '(OR ($EQ AGP-EQ-P 'NA) ($EQ AGP-EQ-P 'FALSE)))
  (ACTION
   '($SETQ FCP 'OK)))

(RULE040
  (TRANS
   '(if   temperature of hose fitting at pump pressure port is
          greater than temperature of hose fitting at pump case
          drain port by 28 degrees celsius is not applicable or false
      and temperature of hose fitting at pump case drain port
          is greater than 102 degrees celsius is not applicable or
          false
     then flight control pump is ok))
  (PREMISE
   '(AND (OR ($EQ AGB-28 'NA) ($EQ AGB-28 'FALSE))
         (OR ($EQ BG-102 'NA) ($EQ BG-102 'FALSE))))
  (ACTION
   '($SETQ FCP 'OK)))
```

```
(RULE041
  (TRANS
   '(if    temperature differential between inlet and outlet port
           of flight control pump is abnormal is not applicable or
           false
     then flight control pump is ok))
  (PREMISE
   '(OR ($EQ TDA-FCP 'NA) ($EQ TDA-FCP 'FALSE)))
  (ACTION
   '($SETQ FCP 'OK)))

(RULE042
  (TRANS
   '(if    accumulator gage pressure indication is equal to cockpit
           pressure indication is true
     then flight control pump is failed))
  (PREMISE
   '($EQ AGP-EQ-P 'TRUE))
  (ACTION
   '($SETQ FCP 'FAILED)))

(RULE043
  (TRANS
   '(if    temperature of hose fitting at pump pressure port is
           greater than temperature of hose fitting at pump case
           drain port by 28 degrees celsius is true
       or  temperature of hose fitting at pump case drain port
           is greater than 102 degrees celsius is true
     then flight control pump is failed))
  (PREMISE
   '(OR ($EQ AGB-28 'TRUE) ($EQ BG-102 'TRUE)))
  (ACTION
   '($SETQ FCP 'FAILED)))

(RULE044
  (TRANS
   '(if    temperature differential between inlet and outlet port
           of flight control pump is abnormal is true
     then flight control pump is failed))
  (PREMISE
   '($EQ TDA-FCP 'TRUE))
  (ACTION
   '($SETQ FCP 'FAILED)))

(RULE045
  (TRANS
   '(if    pressure indication is high is false
     then accumulator gage pressure is equal to cockpit pressure
          indication is not applicable))
  (PREMISE
   '($EQ PH 'FALSE))
  (ACTION
   '($SETQ AGP-EQ-P 'NA)))

(RULE046
  (TRANS
   '(if    pressure indication is low is false
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        and pressure indication is zero is false
        and pressure indication is fluctuating is false
        and accumulator gage is fluctuating is either not applicable
            or false
       then temperature of hose fitting at pump pressure port is
            greater than temperature of hose fitting at pump case
            drain port by 28 degrees celsius))
  (PREMISE
    '(AND ($EQ PL 'FALSE) ($EQ PZ 'FALSE) ($EQ PFL 'FALSE)
          (OR ($EQ AG-F 'NA) ($EQ AG-F 'FALSE))))
  (ACTION
    '($SETQ AGB-28 'NA)))

(RULE047
  (TRANS
    '(if   pressure indication is low is false
        and pressure indication is zero is false
        and pressure indication is fluctuating is false
        and accumulator gage is fluctuating is either not applicable
            or false
       then temperature of hose fitting at pump case drain port is
            greater than 102 degrees celsius is not applicable))
  (PREMISE
    '(AND ($EQ PL 'FALSE) ($EQ PZ 'FALSE) ($EQ PFL 'FALSE)
          (OR ($EQ AG-F 'NA) ($EQ AG-F 'FALSE))))
  (ACTION
    '($SETQ BG-102 'NA)))

(RULE048
  (TRANS
    '(if   temperature of return line tube assembly at flight control
            manifold is greater than or equal to temperature of hose
            fitting at pump pressure port is not applicable or true
       then temperature differential between inlet and outlet port
            of flight control pump is abnormal is not applicable))
  (PREMISE
    '(OR ($EQ TC-GTE-TA 'NA) ($EQ TC-GTE-TA 'TRUE)))
  (ACTION
    '($SETQ TDA-FCP 'NA)))

(RULE049
  (TRANS
    '(if   pressure indication is low is false
       then temperature of return line tube assembly at flight control
            manifold is greater than or equal to temperature of hose
            fitting at pump pressure port is not applicable))
  (PREMISE
    '($EQ PL 'FALSE))
  (ACTION
    '($SETQ TC-GTE-TA 'NA)))

(RULE050
  (TRANS
    '(if   temperature of return line tube assembly at flight control
            manifold is greater than or equal to temperature of hose
            fitting at pump pressure port is not applicable
            or false
       then flight control manifold is ok))
```

```
    (PREMISE
     '(OR ($EQ TC-GTE-TA 'NA) ($EQ TC-GTE-TA 'FALSE)))
    (ACTION
     '($SETQ FCM 'OK)))

  (RULE051
    (TRANS
     '(if   temperature of return line tube assembly at flight control
            manifold is greater than or equal to temperature of hose
            fitting at pump pressure port is true
       then flight control manifold is failed))
    (PREMISE
     '($EQ TC-GTE-TA 'TRUE))
    (ACTION
     '($SETQ FCM 'FAILED)))

  (RULE052
    (TRANS
     '(if   temperature differential between inlet and outlet port
            of pressure reduce valve is abnormal is not applicable
            or false
      then  pressure reduce valve is ok))
    (PREMISE
     '(OR ($EQ TDA-PRV 'NA) ($EQ TDA-PRV 'FALSE)))
    (ACTION
     '($SETQ PRV 'OK)))

  (RULE053
    (TRANS
     '(if   temperature differential between inlet and outlet port
            of pressure reduce valve is abnormal is true
      then  pressure reduce valve has failed))
    (PREMISE
     '($EQ TDA-PRV 'TRUE))
    (ACTION
     '($SETQ PRV 'FAILED)))

  (RULE054
    (TRANS
     '(if   temperature differential between inlet and outlet port
            of flight boost accumulator is abnormal is not applicable
            or false
      then  flight boost accumulator is ok))
    (PREMISE
     '(OR ($EQ TDA-FBA 'NA) ($EQ TDA-FBA 'FALSE)))
    (ACTION
     '($SETQ FBA 'OK)))

  (RULE055
    (TRANS
     '(if   temperature differential between inlet and outlet port
            of flight boost accumulator is abnormal is true
      then  flight boost accumulator has failed))
    (PREMISE
     '($EQ TDA-FBA 'TRUE))
    (ACTION
     '($SETQ FBA 'FAILED)))
```

```
(RULE056
  (TRANS
    '(if   temperature differential between inlet and outlet port
           of hydraulic tank is abnormal is not applicable
           or false
     then  hydraulic tank is ok))
  (PREMISE
    '(OR ($EQ TDA-HT 'NA) ($EQ TDA-HT 'FALSE)))
  (ACTION
    '($SETQ HT 'OK)))

(RULE057
  (TRANS
    '(if   temperature differential between inlet and outlet port
           of hydraulic tank is abnormal is true
     then  hydraulic tank has failed))
  (PREMISE
    '($EQ TDA-HT 'TRUE))
  (ACTION
    '($SETQ HT 'FAILED)))

(RULE058
  (TRANS
    '(if   temperature differential between inlet and outlet port
           of pressure filter is abnormal is not applicable
           or false
     then  pressure filter is ok))
  (PREMISE
    '(OR ($EQ TDA-PF 'NA) ($EQ TDA-PF 'FALSE)))
  (ACTION
    '($SETQ PF 'OK)))

(RULE059
  (TRANS
    '(if   temperature differential between inlet and outlet port
           of pressure filter is abnormal is true
     then  pressure filter has failed))
  (PREMISE
    '($EQ TDA-PF 'TRUE))
  (ACTION
    '($SETQ PF 'FAILED)))

(RULE060
  (TRANS
    '(if   temperature differential between inlet and outlet port
           of return filter is abnormal is not applicable
           or false
     then  return filter is ok))
  (PREMISE
    '(OR ($EQ TDA-RF 'NA) ($EQ TDA-RF 'FALSE)))
  (ACTION
    '($SETQ RF 'OK)))

(RULE061
  (TRANS
    '(if   temperature differential between inlet and outlet port
           of return filter is abnormal is true
     then  return filter has failed))
```

```
   (PREMISE
    '($EQ TDA-RF 'TRUE))
   (ACTION
    '($SETQ RF 'FAILED)))

 (RULE062
   (TRANS
    '(if   temperature of return line tube assembly at flight control
           manifold is greater than or equal to temperature of hose
           fitting at pump pressure port is not applicable or true
      then temperature differential between inlet and outlet port
           of pressure reduce valve is abnormal is not applicable))
   (PREMISE
    '(OR ($EQ TC-GTE-TA 'NA) ($EQ TC-GTE-TA 'TRUE)))
   (ACTION
    '($SETQ TDA-PRV 'NA)))

 (RULE063
   (TRANS
    '(if   temperature of return line tube assembly at flight control
           manifold is greater than or equal to temperature of hose
           fitting at pump pressure port is not applicable or true
      then temperature differential between inlet and outlet port
           of flight boost accumulator is abnormal is not applicable))
   (PREMISE
    '(OR ($EQ TC-GTE-TA 'NA) ($EQ TC-GTE-TA 'TRUE)))
   (ACTION
    '($SETQ TDA-FBA 'NA)))

 (RULE064
   (TRANS
    '(if   temperature of return line tube assembly at flight control
           manifold is greater than or equal to temperature of hose
           fitting at pump pressure port is not applicable or true
      then temperature differential between inlet and outlet port
           of hydraulic tank is abnormal is not applicable))
   (PREMISE
    '(OR ($EQ TC-GTE-TA 'NA) ($EQ TC-GTE-TA 'TRUE)))
   (ACTION
    '($SETQ TDA-HT 'NA)))

 (RULE065
   (TRANS
    '(if   temperature of return line tube assembly at flight control
           manifold is greater than or equal to temperature of hose
           fitting at pump pressure port is not applicable or true
      then temperature differential between inlet and outlet port
           of pressure filter is abnormal is not applicable))
   (PREMISE
    '(OR ($EQ TC-GTE-TA 'NA) ($EQ TC-GTE-TA 'TRUE)))
   (ACTION
    '($SETQ TDA-PF 'NA)))

 (RULE066
   (TRANS
    '(if   temperature of return line tube assembly at flight control
           manifold is greater than or equal to temperature of hose
           fitting at pump pressure port is not applicable or true
```

```
      then  temperature differential between inlet and outlet port
            of return filter is abnormal is not applicable))
    (PREMISE
     '(OR ($EQ TC-GTE-TA 'NA) ($EQ TC-GTE-TA 'TRUE)))
    (ACTION
     '($SETQ TDA-RF 'NA)))

  (RULE067
    (TRANS
     '(if   trapped air in system is not applicable or false
      then  do not loosen flexible supply line to flight control pump))
    (PREMISE
     '(OR ($EQ TA-IN-SYS 'NA) ($EQ TA-AT-SYS 'FALSE)))
    (ACTION
     '($SETQ L-FS-L 'NO)))

  (RULE068
    (TRANS
     '(if   trapped air in system is true
      then  do loosen flexible supply line to flight control pump))
    (PREMISE
     '($EQ TA-IN-SYS 'TRUE))
    (ACTION
     '($SETQ L-FS-L 'YES)))

  (RULE069
    (TRANS
     '(if   trapped air in system is not applicable or false
      then  do not loosen line to flight boost accumulator))
    (PREMISE
     '(OR ($EQ TA-IN-SYS 'NA) ($EQ TA-AT-SYS 'FALSE)))
    (ACTION
     '($SETQ L-FBA-L 'NO)))

  (RULE070
    (TRANS
     '(if   trapped air in system is true
      then  do loosen line to flight boost accumulator))
    (PREMISE
     '($EQ TA-IN-SYS 'TRUE))
    (ACTION
     '($SETQ L-FBA-L 'YES)))

  (RULE071
    (TRANS
     '(if   pressure is zero is false
      then  trapped air at system is not applicable))
    (PREMISE
     '($EQ PZ 'FALSE))
    (ACTION
     '($SETQ TA-IN-SYS 'NA))))

~ #####   KNOWLEDGE BASE INITIALIZATION   ###########################


(FIND-PARAMETER-RULE-RELATIONS *PARAMETER-GROUP* *RULE-GROUP*)
```

```
(INITIALIZE-KB *PARAMETER-GROUP* *RULE-GROUP*)
(HELP)
```

END

DTIC

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